POLYCRYSTALLINE SILICON FILM CONTAINING Ni

BACKGROUND OF THE INVENTION

FIELD OF INVENTION

The present invention related to a polycrystalline silicon film containing Ni which is formed by crystallizing an amorphous silicon layer containing nickel.

DISCUSSION OF RELATED ART

In view of performance, low temperature polysilicon, of which product cost is low owing to its low formation temperature and which also enables to provide an large-scale display area, is as good as high temperature polysilicon.

There are various methods for forming low temperature polysilicon such as solid phase crystallization(SPC), laser crystallization and the like.

Enabling to provide low temperature crystallization under 400℃, which is disclosed in [Hiroyaki Kuriyama, et. al, Jpn. J. Appl. Phys. 31, 4550 (1992)], the laser crystallization fails to provide uniform crystallization and has difficulty in forming polysilicon on a substrate of an large area due to an expensive apparatus and low productivity.

When polysilicon is formed by solid phase crystallization, uniform crystallites are attained in use of an inexpensive apparatus. However, solid phase crystallization requires high temperature and long processing time of crystallization, which is hardly applied to forming polysilicon on a glass substrate, thereby having high production cost.

A new method of crystallizing amorphous silicon at low temperature, which is so-called metal induced crystallization, is disclosed in [M.S.Haque, et. al, J. Appl. Phys. 79, 7529(1996)]. Metal induced crystallization crystallizes amorphous silicon by contacting

amorphous silicon with a specific kind of metal which induces crystallization of silicon and then by carrying out annealing, thereby enabling to lower crystallization temperature.

In Ni-induced crystallization, crystallization is accelerated by the $NiSi_2$ which is the final phase of Ni silicide and works as a crystal nucleus, which is disclosed in [C. Hayzelden, et. al, J. Appl. Phys. 73, 8279 (1993)]. As a matter of fact, $NiSi_2$, of which lattice constant is 5.406Å similar to 5.430Å of silicon, has the similar structure of silicon. Thus, $NiSi_2$ works as a crystal nucleus of amorphous silicon, accelerating crystallization to the direction <111>, which is disclosed in [C. Hayzelden, et. al, Appl. Phys. Lett. 60, 225 (1992)]. The crystallization of amorphous silicon is accelerated by metal species.

The metal-induced crystallization is affected by time and temperature of annealing as well as quantity of metal, of which crystallization time is lowered in general while the quantity of metal increases.

Metal induced crystallization has a merit of low crystallization temperature, unfortunately requiring long thermal process time over 20 hours at 500℃. Therefore, this method has many difficulties in being applied to mass production of polycrystalline silicon.

As quantity of metal increases, so metal induced crystallization becomes effective. However, intrinsic characteristics of a silicon film are changed due to metal contamination in the crystallized silicon film.

As mentioned in the above explanation, despite the merit of low temperature crystallization, metal-induced crystallization has a fatal defect that the intrinsic characteristics of a silicon film is changed due to the metal contamination as metal

having been used for crystallization remains in the crystallized silicon film.

Accordingly, the quantity of the metal remaining in the silicon film crystallized by metal-induced crystallization should be optimized to be applied to the current semiconductor device fabrication.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a polycrystalline silicon film containing Ni that substantially obviate one or more of the problems due to limitations and disadvantages of the related art.

The object of the present invention is to provide a polycrystalline silicon film which contains metal species properly in quantity by minimizing the metal contamination fatal to the polysilicon formed by metal-induced crystallization in order to be used for the fabrication of semiconductor devices.

Additional features and advantages of the invention will be set forth in the description which follows and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, the present invention includes a polycrystalline silicon film wherein the polycrystalline film contains Ni atoms of which density ranges 2×10^{17} to 5×10^{19} atoms/cm^3 in average and comprises a plurality of bar-like silicon crystallites.

In another aspect, the present invention includes a polycrystalline silicon film

wherein the polycrystalline film contains Ni atoms of which density ranges 2×10^{17} to 5×10^{19} atoms/㎤, comprises a plurality of bar-like silicon crystallites and is formed on an insulating substrate.

In a further aspect, the present invention includes a polycrystalline silicon film wherein the polycrystalline film contains metal of which density ranges 2×10^{17} to 5×10^{19} atoms/㎤ and comprises a plurality of bar-like silicon crystallites and wherein the metal is a catalyst for metal induced crystallization of silicon.

In a further aspect, the present invention includes a polycrystalline silicon film wherein the polycrystalline film contains metal of which density ranges 2×10^{17} to 5×10^{19} atoms/㎤ and the polycrystalline silicon film comprises a plurality of bar-like silicon crystallites and wherein the metal is a catalyst for metal induced crystallization of amorphous silicon.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE ATTACHED DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this application, illustrate embodiments of the inventing and together with the description serve to explain the principle of the invention.

In the drawings:

Fig. 1 shows a cross-sectional view of a polysilicon film according to a first embodiment of the present invention;

Fig. 2 shows a cross-sectional view of a polysilicon film according to a second embodiment of the present invention;

Fig. 3 shows a first example of the secondary ion mass-spectroscopy of a polysilicon film formed by the embodiment of the present invention;

Fig. 4 shows electrical characteristics of the polysilicon film containing Ni suggested in Fig. 3;

Fig. 5 shows a second example of the secondary ion mass-spectroscopy of a polysilicon film formed by the embodiment of the present invention;

Fig. 6 shows electrical characteristics of the polysilicon film containing Ni suggested in Fig. 5;

Fig. 7 shows a third example of the secondary ion mass-spectroscopy of a polysilicon film formed by the embodiment of the present invention;

Fig. 8 shows electrical characteristics of the polysilicon film containing Ni suggested in Fig. 7;

Fig. 9 shows a graph of an electrical conductivity activation energy vs. number of Ni atoms contained in the polysilicon film formed by the embodiment of the present invention;

Fig. 10 shows field effect mobility of a TFT fabricated in use of the polysilicon film formed by another embodiment of the present invention in accordance with the Ni containment;

Figs. 11A to 11D show TEM pictures and diffraction patterns of a polysilicon film according to the Ni containment; and

Figs. 12A to 12C show the crystallization of a polysilicon film according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

In general, the metal induced crystallization is affected by time and temperature of annealing as well as quantity of metal, of which crystallization time is lowered in general while the quantity of metal increases. In this case, annealing time is dramatically shortened and annealing temperature is greatly reduced in metal induced crystallization provided that electric field is applied to an amorphous silicon film containing metal [Jin Jang, et. al, Nature, Vol. 395, pp. 481-483 (1998)].

The polysilicon film of the present invention is distinguished by the facts that the film is fabricated by metal induced crystallization in use of Ni and that Ni atoms exist in the film to the extremely small amount between 2×10^{17}atoms/㎤ and 5×10^{19}atoms/㎤.

The polysilicon film of the present invention is formed by metal induced crystallization including the steps of adding small quantity of Ni to an amorphous silicon film and carrying out rapid thermal process or another thermal treatment while electric field is applied thereon.

Ni is a catalyst for crystallizing a silicon film. Besides, various metal species such as Au or Co working as catalyst for metal induced crystallization also enable to be used for the crystallization.

From now on, the description will be followed by the case that Ni is used as a catalyst for metal induced crystallization.

The steps of forming a polysilicon film are explained in the following description of the present invention.

An amorphous silicon film is deposited on an insulating layer. Then, the

amorphous silicon film is put into a rapid thermal annealing system. Small amount of Ni is deposited on a substrate by sputtering and, successively, thermal treatment is carried out as well as electric field is applied thereon. In this case, temperature of the thermal treatment ranges 400 to 500℃.

Power for depositing Ni ranges 1 to 100W, which controls the deposition rate by being manipulated. The deposition rate means an average amount presumed from deposition area, Ni density and deposition time after total number of Ni atoms in the crystallized polysilicon film has been calculated by SIMS(secondary ion mass spectroscopy). Such method of metal deposition is simple and important in controlling the amount of metal existing in the film. In this case, the size of the sample is 100 x 100 mm^2 and DC bias applied during thermal treatment ranges 0 to 1000 V.

Initial vacuum level for Ni deposition is under 10^{-6}Torr and a lamp is arranged in a heating block to heat a sample uniformly. An amorphous silicon film is heated by a ray or heat transferred through a substrate. Metal electrodes are contacted coplanar with both ends of the sample in order to apply uniform electric field to both ends of amorphous silicon. In this case, the metal for the electrodes is made of MoW or Cr and the contact resistance is 6Ω at a room temperature.

Fig. 1 shows a cross-sectional view of a polysilicon film according to a first embodiment of the present invention.

Referring to Fig. 1, a polysilicon film 11 which is formed by the above-mentioned method and which contains small amount of Ni is on an insulating substrate 10 such as a glass substrate.

Fig. 2 shows a cross-sectional view of a polysilicon film according to a second embodiment of the present invention.

Referring to Fig. 2, an insulating layer 21 as a buffer layer is formed on an insulating substrate 20 such as a glass substrate. A polysilicon film 22 which is formed by the above-mentioned method and which contains small amount of Ni is on an insulating substrate 20.

Fig. 3 shows a first example of the secondary ion mass-spectroscopy of a polysilicon film formed by the embodiment of the present invention.

Referring to Fig. 3, Ni atoms exist in the polysilicon film to the amount between $4 \times 10^{18}/cm^3$ (denoted by line(a)) and $2 \times 10^{18}/cm^3$ (denoted by line(b)) in average.

Fig. 4 shows electrical conductivity of the polysilicon film containing Ni suggested in Fig. 3.

Referring to Fig. 4, each electrical conductivity activation energy of a polysilicon film containing Ni is 0.52 eV(denoted by line(a)) and 0.62 eV(line(b)), respectively. The graph shows the same activated form of a conventional polysilicon film.

Fig. 5 shows a second example of the secondary ion mass-spectroscopy of a polysilicon film formed by the embodiment of the present invention.

Referring to Fig. 5, Ni atoms exist in the polysilicon film to the amount between $9 \times 10^{17}/cm^3$(denoted by line(c)) and $6 \times 10^{17}/cm^3$(denoted by line(d)) in average.

Fig. 6 shows electrical characteristics of the polysilicon film containing Ni suggested in Fig. 5.

Referring to Fig. 6, each electrical conductivity activation energy of a polysilicon film containing Ni is 0.64 eV(denoted by line(c)) and 0.71 eV(line(d)).

Fig. 7 shows a third example of the secondary ion mass-spectroscopy of a polysilicon film formed by the embodiment of the present invention.

Referring to Fig. 7, Ni atoms exist in the polysilicon film to the amount of about `1

$\times 10^{18}/cm^3$ in average.

Fig. 8 shows electrical conductivity of the polysilicon film containing Ni suggested in Fig. 7.

Referring to Fig. 8, each electrical conductivity activation energy of a polysilicon film containing Ni is 0.62 eV.

Fig. 9 shows a graph of an electrical conductivity activation energy vs. number of Ni atoms contained in the polysilicon film formed by the embodiment of the present invention.

Referring to Fig. 9, the graph shows electrical conductivity activation energy when Ni atoms exist in the polysilicon film to the amount between $10^{17}/cm^3$ and $10^{19}/cm^3$ in average.

As quantity of Ni increases in the film, so do acceptors within a silicon band gap. Thus, electrical conductivity activation energy decreases. By referring the drawing, as most of Ni atoms do not form acceptors in the polysilicon film, such silicon material can be used for semiconductor device fabrication provided that number of Ni atoms in the film is under $2\times 10^{19}/cm^3$ in average.

Fig. 10 shows field effect mobility of a TFT fabricated in use of the polysilicon film formed by another embodiment of the present invention in accordance with the Ni containment.

Referring to Fig. 10, crystallization is achieved within 10 minutes by applying electric field during crystallization of which temperature is about 500℃.

The maximum value of mobility appears provided that Ni containment is $2.96\times 10^{19}/cm^3$.

Mobility decreases greatly provided that Ni containment is over $10^{20}/cm^3$.

It is impossible to achieve the crystallization experimentally within 10 minutes provided that Ni containment is under $1 \times 10^{18}/cm^3$.

Figs. 11A to 11D show TEM pictures and diffraction patterns of a polysilicon film according to the Ni containment.

Fig. 11A shows a picture of TEM and diffraction patterns of a polysilicon film containing Ni atoms of 1.6×10^{17} atoms/cm^3 in average.

Referring to Fig. 11A, crystallites 12 of leaf-like feature is verified in an amorphous silicon region 11, showing that crystallization is achieved locally instead of total crystallization of the film.

Fig. 11B shows a picture of TEM and diffraction patterns of a polysilicon film containing Ni atoms of 4.8×10^{17} atoms/cm^3 in average.

Referring to Fig. 11B, crystallites 13 of bar-like feature is verified, and whole amorphous silicon is crystallized uniformly.

Fig. 11C shows a picture of TEM and diffraction patterns of a polysilicon film containing Ni atoms of 1.6×10^{19} atoms/cm^3 in average.

Referring to Fig. 11C, it is noted that the film is crystallized by crystallites 13 of bar-like feature, and whole amorphous silicon is crystallized uniformly.

Fig. 11D shows a picture of SEM and diffraction patterns of a polysilicon film containing Ni atoms of 3×10^{20} atoms/cm^3 in average.

Referring to Fig. 11D, bar-like crystallites are not identified in the drawing, and the whole film is filled with crystallites 14 of small circle-like feature. Such polysilicon fails to be used for fabricating solar cells, thin film transistors, and the like.

Figs. 12A to 12C show the crystallization of a polysilicon film according to the

present invention.

Referring to Fig. 12A, each crystallite of bar-like feature grow from a nucleus for crystallization in a certain direction by the movement of $NiSi_2$ in the early stage of crystallization, respectively.

Referring to Fig. 12B, this crystallite of bar-like feature grows continuously until this crystallite collides with other crystallites grown from other nucleuses and stops its growth.

Referring to Fig. 12C, an amorphous silicon thin film is crystallized by a number of crystallites of bar-like feature.

As mentioned in the above description of the present invention, a polysilicon film containing Ni of which density ranges 2×10^{17} and 5×10^{19} atoms/cm³ consists of bar-like silicon crystallites, and the whole part of the polysilicon film is crystallized uniformly.

Such a polysilicon film according to the present invention avoids metal contamination usually generated in a conventional method of metal induced crystallization.

Accordingly, the polysilicon film of the present invention is applied to the fabrication of a TFT-LCD, a solar cell, etc. instead of polysilicon crystallized by the current laser crystallization.

It will be apparent to those skilled in the art that various modifications and variations can be made in polycrystalline silicon containing Ni of the present invention without departing from the spirit or scope of the inventions. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and equivalents.